Computer Graphics

Lecture 1
Introduction

Doç. Dr. Mehmet Göktürk
Grading Policy

Midterm 30%
Final 40%
Project & Homeworks 25%
Attendance & Participation 5%

• Attendance & Participation is important for borderline students
Course Outline

1. Introduction, Survey of Computer Graphics (MG)
2. Overview of Graphics Systems, Graphics Hardware (MG)
3. Output Primitives, Drawing algorithms filling algorithms (MG)
4. 2D Geometric Transformations, 2D Viewing and Clipping algorithms (MG)
5. 3D Concepts (MG), Introduction to 3D object representations (MG)
6. 3D Geometric and Modeling Transformations, 3D Viewing (MG)
7. Visible Surface Methods (YG)
8. Illumination Models (YG)
9. Flat, Gouraud, Phong Shading (YG)
10. Texture, Bump Mapping (YG)
11. Object Space Algorithms (YG)
12. Color concepts (YG)
Textbook

• Computer Graphics, Donald Hearn, M. Pauline Baker; Prentice Hall (C version or the old one) Prentice Hall; ISBN: 0135309247

• TEXTBOOK IS REQUIRED !!!
  (copies are ok)
Google-groups

- gyte-bil461 @ googlegroups.com

- Video supplements: http://nptel.iitm.ac.in/video.php?subjectId=106106090
What is Computer Graphics?

Geometric Modeling

Image Synthesis
What is Computer Graphics?

Hidden Surface Elimination
What is Computer Graphics?

Shadows
What is Computer Graphics?

Texture Mapping
What is Computer Graphics?

Complex Geometry
What is Computer Graphics?

Transparency
What is Computer Graphics?

Environment Mapping
What is Computer Graphics?

Games
What is Computer Graphics?

Medical Applications
What is Computer Graphics?

Computer Aided Design (CAD)
What is Computer Graphics?

Scientific Visualisation
What is Computer Graphics?

Films and Animation

Pixar: Monster’s Inc.

Square: Final Fantasy
A lot of stuff!
Image Processing & Computer Vision

- Image enhancement
- Feature extraction
- Pattern recognition
- 3D model extraction

IMAGE PROCESSING AND COMPUTER GRAPHICS ARE REVERSE IN RESPECTIVE DIRECTIONS ???
Computer Graphics creates images from models while Image Processing creates models from images.
Why Study Computer Graphics?

- Graphics is cool
  - I like to see what I’m doing
  - I like to show people what I’m doing
- Graphics is interesting
  - Involves simulation, algorithms, architecture…
- I’ll never get an Oscar for my acting
  - But maybe I’ll get one for my CG special effects
- Graphics is fun
Questions?

- ???
- (class participation is 5%)
Display Technologies

- Cathode Ray Tubes (CRTs)
  - Most common display device today
  - Evacuated glass bottle
  - Extremely high voltage
  - Heating element (filament)
  - Electrons pulled towards anode focusing cylinder
  - Vertical and horizontal deflection plates
  - Beam strikes phosphor coating on front of tube
Electron Gun

- Contains a filament that, when heated, emits a stream of electrons
- Electrons are focused with an electromagnet into a sharp beam and directed to a specific point of the face of the picture tube
- The front surface of the picture tube is coated with small phospher dots
- When the beam hits a phospher dot it glows with a brightness proportional to the strength of the beam and how often it is excited by the beam
Display Devices

**Vector display**
- Only lines can be drawn.
- Locations are converted to analog voltage applied to the deflection circuit of the CRT.
- Lines drawn by gradual change of voltage.
- Also known as *random scan*.

**Raster display**
- Discrete grid of elements (frame buffers pixels).
- Arbitrary shapes can be drawn by setting the “right” elements.
- The frame buffer is scanned, one line at a time, to preserve the image on the CRT.
Ivan Sutherland (1963) - SKETCHPAD

- pop-up menus
- constraint-based drawing
- hierarchical modeling
Display hardware

- vector displays
  - 1963 – modified oscilloscope
  - 1974 – Evans and Sutherland Picture System
- raster displays
  - 1975 – Evans and Sutherland frame buffer
  - 1980s – cheap frame buffers → bit-mapped personal computers
  - 1990s – liquid-crystal displays → laptops
  - 2000s – micro-mirror projectors → digital cinema
- other
  - stereo, head-mounted displays
  - autostereoscopic displays
  - tactile, haptic, sound
Display Technologies: CRTs

- Vector Displays
  - Anybody remember *Battlezone? Tempest?*
Display Technologies: CRTs

- Vector Displays
  - Early computer displays: basically an oscilloscope
  - Control X,Y with vertical/horizontal plate voltage
  - Often used intensity as Z

- **Name two disadvantages**
  - Just does wireframe
  - Complex scenes ➔ visible flicker
Display Technologies: CRTs

- Raster Displays
  - Raster: A rectangular array of points or dots
  - Pixel: One dot or picture element of the raster
  - Scan line: A row of pixels
Display Technologies: CRTs

- **Raster Displays**
  - Black and white television: an oscilloscope with a fixed scan pattern: left to right, top to bottom
  - To paint the screen, computer needs to synchronize with the scanning pattern of raster
    - Solution: special memory to buffer image with scan-out synchronous to the raster. We call this the *framebuffer*. 
Display Technologies: CRTs

- Phosphorus
  - Fluorescence: Light emitted while the phosphor is being struck by electrons
  - Phosphorescence: Light emitted once the electron beam is removed
  - Persistence: The time from the removal of the excitation to the moment when phosphorescence has decayed to 10% of the initial light output
Display Technologies: CRTs

- Raster Displays
  - Frame must be “refreshed” to draw new images
  - As new pixels are struck by electron beam, others are decaying
  - Electron beam must hit all pixels frequently to eliminate flicker
  - Critical fusion frequency
    - Typically 60 times/sec
    - Varies with intensity, individuals, phosphor persistence, lighting...
Display Technologies: CRTs

- Raster Displays
  - Interlaced Scanning
  - Assume can only scan 30 times / second
  - To reduce flicker, divide frame into two “fields” of odd and even lines

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<tr>
<td>Frame</td>
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Display Technologies: CRTs

- Raster Displays
  - Scanning (left to right, top to bottom)
    - Vertical Sync Pulse: Signals the start of the next field
    - Vertical Retrace: Time needed to get from the bottom of the current field to the top of the next field
    - Horizontal Sync Pulse: Signals the start of the new scan line
    - Horizontal Retrace: The time needed to get from the end of the current scan line to the start of the next scan line
Display Technology: Color CRTs

- Color CRTs are much more complicated
  - Requires manufacturing very precise geometry
  - Uses a pattern of color phosphors on the screen:
    - Why red, green, and blue phosphors?

Delta electron gun arrangement

In-line electron gun arrangement
Display Technology: Color CRTs

- Color CRTs have
  - Three electron guns
  - A metal shadow mask to differentiate the beams

© M. Gokturk
Triads and color mixing

SMPTE color bars

closeup on a Sony Trinitron monitor
Triads versus pixels

integral pixel font (Sony Trinitron)
integral pixel font (IBM LCD)
antialiased font (Adobe Acrobat)
subpixel font (Adobe Cooltype)
Display Technology: Raster

- **Raster CRT pros:**
  - Allows solids, not just wireframes
  - Leverages low-cost CRT technology (i.e., TVs)
  - Bright! Display *emits* light

- **Cons:**
  - Requires screen-size memory array
  - Discreet sampling (pixels)
  - Practical limit on size (call it 40 inches)
  - Bulky
  - Finicky (convergence, warp, etc)
Terminology

• **Pixel**: *Picture element*
  - Smallest accessible element in a picture.
  - Usually rectangular or circular in shape.

• **Aspect Ratio**: Ratio between physical dimensions of a pixel (not necessarily 1 !!).

• **Dynamic Range**: The ratio between the minimal (not zero!) and maximal light intensity a display pixel can emit.
Terminology (cont’d)

- **Resolution**: The number of distinguishable rows and columns in the device. Measured in
  - Absolute values (1K x 1K) or,
  - Density values (300 dots per inch).

- **Screen Space**: A discrete 2D Cartesian coordinate system of the screen pixels.

- **Object Space**: The 3D Cartesian coordinate system of the universe, in which the objects (to be displayed) are embedded.
Display Technology: LCDs

- Liquid Crystal Displays (LCDs)
  - LCDs: organic molecules, naturally in crystalline state, that liquefy when excited by heat or E field
  - Crystalline state twists polarized light 90°.
Display Technology: LCDs

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Display Technology: LCDs

- Transmissive & reflective LCDs:
  - LCDs act as light valves, not light emitters, and thus rely on an external light source.
  - Laptop screen: backlit, *transmissive display*
  - Palm Pilot/Game Boy: *reflective display*
Display Technology: Plasma

- Similar in principle to fluorescent light tubes
- Small gas-filled capsules are excited by electric field, emits UV light
- UV excites phosphor
- Phosphor relaxes, emits some other color
Display Technology

- Plasma Display Panel Pros
  - Large viewing angle
  - Good for large-format displays
  - Fairly bright

- Cons
  - Expensive
  - Large pixels (~1 mm versus ~0.2 mm)
  - Phosphors gradually deplete
  - Less bright than CRTs, using more power
Display Technology: DMD / DLP

- Digital Micromirror Devices (projectors) or Digital Light Processing
  - Microelectromechanical (MEM) devices, fabricated with VLSI techniques
Display Technology: DMD / DLP

- DMDs are truly digital pixels
- Vary grey levels by modulating pulse length
- Color: multiple chips, or color-wheel
- Great resolution
- Very bright
- Flicker problems
Display Technologies: Organic LED Arrays

- Organic Light-Emitting Diode (OLED) Arrays
  - The display of the future? Many think so.
  - OLEDs function like regular semiconductor LEDs
  - But they emit light
    - Thin-film deposition of organic, light-emitting molecules through vapor sublimation in a vacuum.
    - Dope emissive layers with...
**Display Technologies: Organic LED Arrays**

**OLED pros:**
- Transparent
- Flexible
- Light-emitting, and quite bright (daylight visible)
- Large viewing angle
- Fast (< 1 microsecond off-on-off)
- Can be made large or small
- Available for cell phones and car stereos

**OLED cons:**
- Not very robust, display lifetime a key issue
- Currently only passive matrix displays
  - Passive matrix: Pixels are illuminated in scanline order, but the lack of phosphorescence causes flicker
  - Active matrix: A polysilicate layer provides thin film transistors at each pixel, allowing direct pixel access and constant illum.
Hardcopy Devices

• **Plotter**: flatbed, drum. Vector based with color pens.
• **Dot Matrix Printer**: Raster based. 7 to 24 scan lines (= pin heads) at a time.
• **Laser Printer**: Raster based. Laser beam discharges a precharged drum to bind a powdered toner. Then, heat fuses the dry toner to paper.
Moving arm flatbed plotter
(courtesy Xynetics, Inc.)

Pinch roll plotter
(courtesy Hewlett-Packard Co.)
Color Printing Technologies

- **Ink Jet**
  Sprays microscopic dots of ink through small holes to form dots on paper.

- **Thermal Wax**
  Creates colors by melting and bonding color wax dots (CMYK or RGB) onto (special) paper.

- **Dye Sublimation**
  Creates *continuous-tone* by heating CMYK dyes until they turn into gas (sublimate), that fuses into the paper.

- **Film Recorder**
  A camera in front of a designated B&W CRT. RGB channels are sent one at a time through an appropriate filter.
Standard Input Devices

• **Keyboard**
  - For alphanumeric input.

• **Mouse/Trackball**
  - A two degrees of freedom device controlled by rolling a ball.
  - Provides relative movement information.
2D Input Devices

• **Joystick**
  - Controlled by potentiometers.
  - Provides relative movement information.

• **Digitizer/Tablet**
  - Controlled by electro-magnetic or sonar sensing.
  - Provides absolute position information.

• **Touch Screen**
  - A CRT screen that can sense pressure on its surface.

• **Light Pen**
  - Synchronized with the CRT scan, it can locate a position on screen.
Light pen  
(courtesy Adage, Inc.)

Joystick  
(courtesy Measurement Systems, Inc.)

Trackball  
(courtesy Measurement Systems, Inc.)
3D Input Devices

- **Dataglove/Polyhemus**
  - Provides six degrees of freedom (three rotation/translation).

- **Head mounted Display**
  - Measures position and orientation like the Polyhemus.

- **Space Ball**
  - Six degrees of freedom sphere (three rotation/translation).
Head-mounted display and tracker
Datagloves
(courtesy Nasa Ames Research Center)

Spaceball
(courtesy Spatial Systems, Inc.)
Image Capture

- **Video Camera**
  - Capture an array of image pixels by CCD.
  - Low resolution.

- **Scanner**
  - Digitizes a hard copy image.
  - High resolution.
Rendering

• 1960s - the visibility problem
  – Roberts (1963), Appel (1967) - hidden-line algorithms
  – Sutherland (1974) – visibility = sorting
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  – Roberts (1963), Appel (1967) - hidden-line algorithms
  – Sutherland (1974) - visibility = sorting
• 1970s - raster graphics
  – Gouraud (1971) - diffuse lighting
  – Blinn (1974) - curved surfaces, texture
  – Phong (1974) - specular lighting
  – Catmull (1974) - Z-buffer hidden-surface
  – Crow (1977) - anti-aliasing
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  – Crow (1977) - anti-aliasing
• early 1980s - global illumination
  – Whitted (1980) - ray tracing
  – Goral, Torrance et al. (1984), Cohen (1985) - radiosity
  – Kajiya (1986) - the rendering equation
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  – Whitted (1980) - ray tracing
  – Goral, Torrance et al. (1984), Cohen (1985) - radiosity
  – Kajiya (1986) - the rendering equation

• late 1980s - photorealism
  – Cook (1984) - trees
  – Perlin (1985) - shading languages
  – Hanrahan and Lawson (1990) - RenderMan
• early 1990s - non-photorealistic rendering
  – Drebin et al. (1988), Levoy (1988) - volume rendering
  – Haeberli (1990) - impressionistic paint programs
  – Salesin et al. (1994-) - automatic pen-and-ink illustration
  – Meier (1996) - painterly rendering
• early 1990s - non-photorealistic rendering
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Modeling

- polygons
- constructive solid geometry
- parametric surfaces
- implicit surfaces
- subdivision surfaces
- particle systems
- volumes
Animation

- scripted
- key-frame interpolation
- inverse kinematics
- dynamics
The graphics pipeline

the traditional pipeline

modeling → animation → rendering

the new pipeline?

3D scanning → motion capture → image-based rendering
Assignment

- Obtain the textbook somehow
- Read chapter 1 and 2
- There will be quiz next week